RP412

SOME STUDIES OF RADIO TRANSMISSION OVER LONG PATHS MADE ON THE BYRD ANTARCTIC EXPEDITION [1]

By L. V. Berkner

ABSTRACT

Field intensity measurements of high-frequency signals (9,000 to 15,000 kc) over long paths, taken at Dunedin, New Zealand, during 1929–30, are given. The relation of diurnal and seasonal changes in signal intensity to the changes of daylight and darkness along the path is discussed. The effect of prolonged darkness along a given path is investigated. Special cases of the variation of signal intensity contrary to that which might be expected from the nature of variation of daylight along the path (during which the increase in attenuation through the daylight portion of the path with time apparently predominates over a slow decrease in the darkness portion of the path) are illustrated. The possibility of a shift in direction of the path of high-frequency signals has been observed under certain circumstances. Evidence of correlation between magnetic disturbances and loss in signal strength along certain paths is indicated, while a lack of such correlation along other paths at nearly the same time and along a reciprocal path is mentioned.

CONTENTS

I. INTRODUCTION

During the radio operations of the Byrd Antarctic expedition (1928–1930), regular observations and measurements were made at the operating bases. This paper deals with the studies of radio signal intensities and fading observations taken on signals arriving over long paths at Dunedin, New Zealand. These observations were made in accordance with a program outlined by the radio section, Bureau of Standards.

The Dunedin field station was located at an altitude of about 500 feet on a mountainside sloping directly to the Pacific Ocean. It was selected because of low noise level and other natural advantages.

II. METHOD OF MEASUREMENT

The general method has been used for several years by the Bureau of Standards for similar recording purposes. The signals were re-

[1] Presented at May 1, 1931, meeting of the International Union of Scientific Radio Telegraphy, American Section, Washington, D. C.

ceived on a high-frequency receiver of the double-detection type. A low intermediate frequency was used because of available equipment. The output of the intermediate frequency amplifier was rectified by means of a square law rectifier and continuously recorded on a Shaw recorder, driven by a synchronous timing motor. The over-all receiver gain was determined by means of a well-shielded local radio-frequency generator, using the current-resistance drop method for the determination of the input voltage. The receiver gain was adjusted by means of a calibrated attenuator in the intermediate amplifier circuit. The over-all receiver gain was determined with a signal of known value from the local radio-frequency generator at regular intervals of about 10 to 15 minutes during operation.

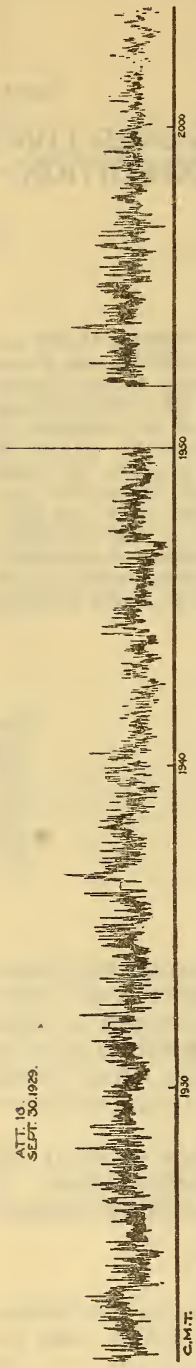

FIGURE 1.—*Typical record of signal intensity as recorded under steady conditions from station G5SW (11,750 kc), Chelmsford, England*

Because of the limitations in apparatus, absolute values of field intensity could be determined with only a moderate degree of accuracy. The comparative values, however, were determined to within about 10 per cent.

III. EXPERIMENTAL DATA

In Figure 1 is indicated the type of record obtained under normal steady conditions. Figures 2 and 3 show typical daily variations of field intensities based on 10-minute mean values taken from the actual records of the Shaw recorder, and smoothed as regards very rapid fading. Figures 4 to 9 show monthly averages of signal intensity measurements made on stations W2XAF, Schenectady, N. Y., U. S. A. (9,530 kc); PCJ, Eindhoven, Holland (9,580 kc); G5SW, Chelmsford, England (11,750 kc); W8XK, Pittsburgh, Pa., U. S. A. (11,800 kc); W6XN, San Francisco, Calif., U. S. A. (12,830 kc); and W2XAD, Schenectady, N. Y., U. S. A. (15,340 kc), for the period June, 1929, to October, 1929. The monthly averages embrace eight or more continuous daily measurements, so that short period disturbances do not greatly affect the averages. Where the number of observations is fewer, the curves have been dotted. Additional measurements of these stations were made during periods of occasional special transmission, occurring usually during the later evening hours, to obtain a more definite idea of the trends during these periods. These are not shown because of their irregularity.

IV. DISCUSSION OF OBSERVED DATA

Probably the simplest scheme for the study of these curves with regard to the nature of the daylight-darkness path traversed is a series of charts, such as is illustrated in Figures 11 and 12. These charts are based on a special projection of the earth, shown in Figure 10, with Dunedin, New Zealand, as a center, and the antipodal point as the boundary circle. A straight line drawn from the center of this

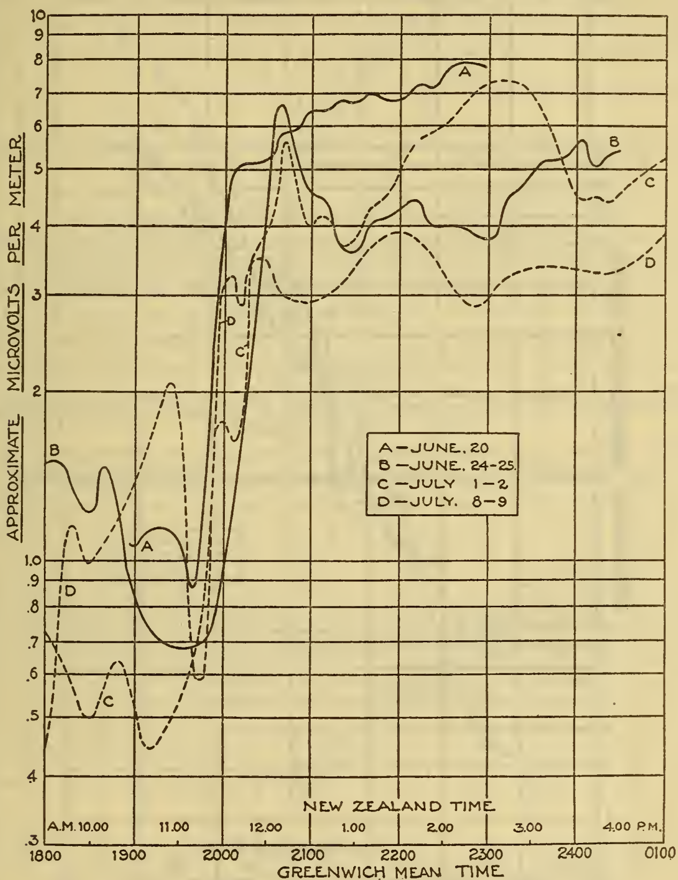

FIGURE 2.—*Typical daily variation of signal intensity of station G5SW, Chelmsford (11,750 kc), observed at Dunedin, New Zealand, 1929*

chart to any point shows the great-circle path and distance. Likewise, any straight line drawn from the center of the daylight-darkness charts to any point corresponding to a similar point on Figure 10 shows the conditions of daylight and darkness along the great-circle path to that point for the time of the chart. Similar studies have been made by Prescott [2] using a type of chart evolved on rectangular coordinates.

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[2] M. L. Prescott, the Diurnal and Seasonal Performance of High-Frequency Radio Transmission Over Various Long-Distance Circuits. Proc. I. R. E.; November, 1930.

The effect of seasonal change upon signal intensities due to the change in the diurnal nature of the path is most marked with antipodal stations. The approximate three-dimensional graphs shown in Figures 13 and 14 are the result of the measurements of stations GBX (10,280 kc), G5SW (11,750 kc), and other southern English stations of about the same frequency, supplemented by about 10,000 aural observations of station GBX made by the Post and Telegraph

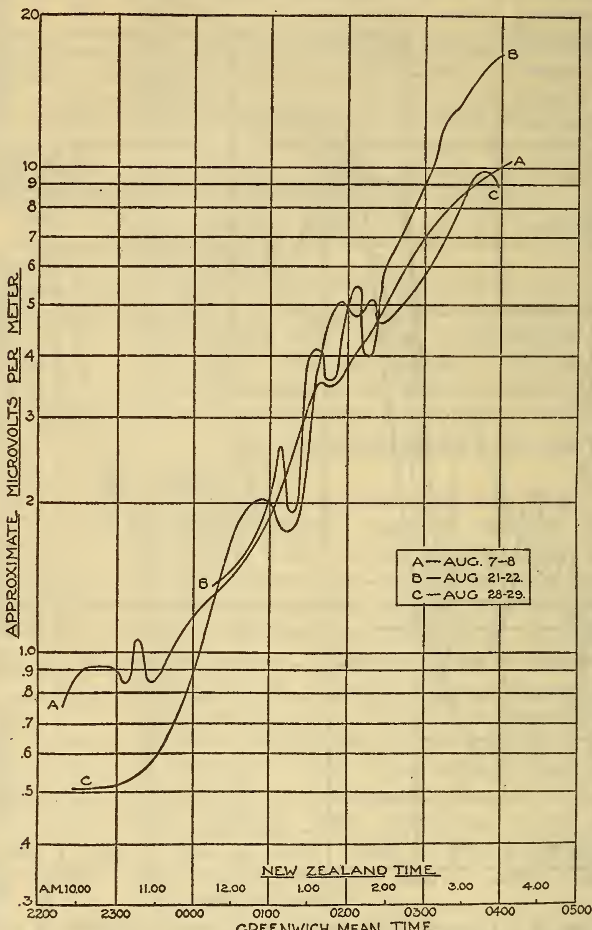


Figure 3.—*Typical daily variation of signal intensity of station W2XAD, Schenectady (15,340 kc), observed at Dunedin, New Zealand, 1929*

Department of the New Zealand Government at the Awarua radio station, and furnished through the courtesy of Mr. Gibbs, chief engineer. Small corrections determined by observation have been made to the measurements of G5SW to reduce them to approximate equivalents of GBX.

It is seen from Figures 13 and 14 that the signal intensity with respect to time of day is just inverted with season; that is, signals are received at noon (N. Z. T.) in June, fading out entirely at midnight

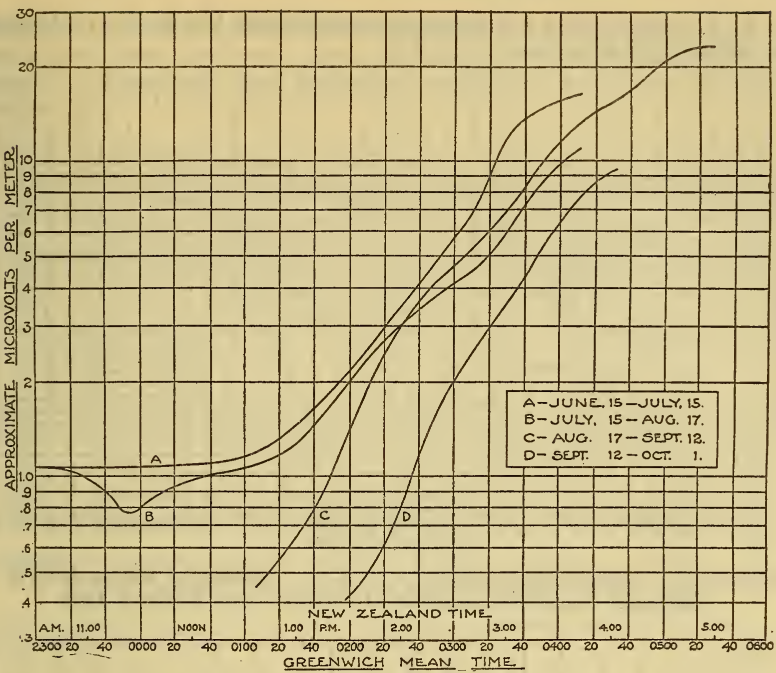


FIGURE 4.—*Average diurnal variation of signal intensity of station W2XAF Schenectady (9,530 kc), observed at Dunedin, New Zealand, 1929*

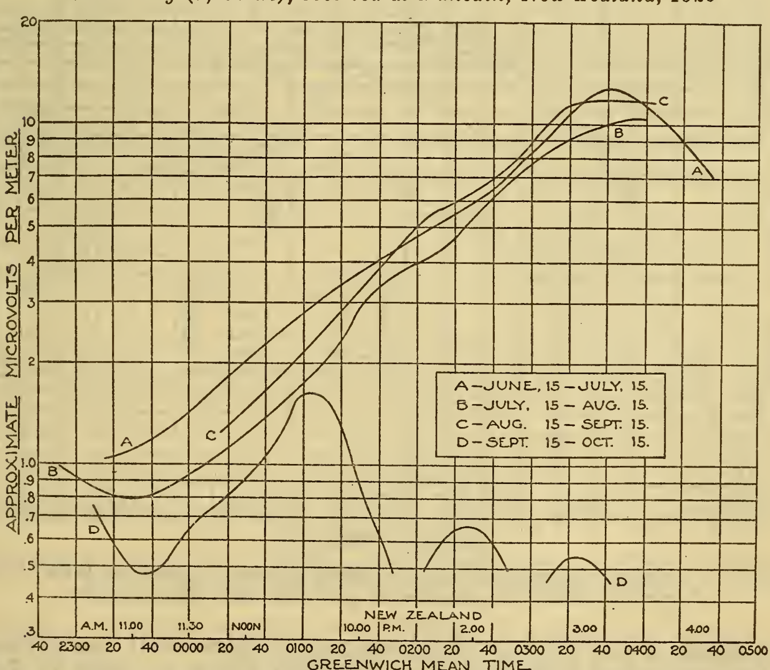


FIGURE 5.—*Average diurnal variation of signal intensity of station W2XAD, Schenectady (15,340 kc), observed at Dunedin, New Zealand, 1929*

(N. Z. T.), while they are received at midnight (N. Z. T.) in December, fading out by noon (N. Z. T.).

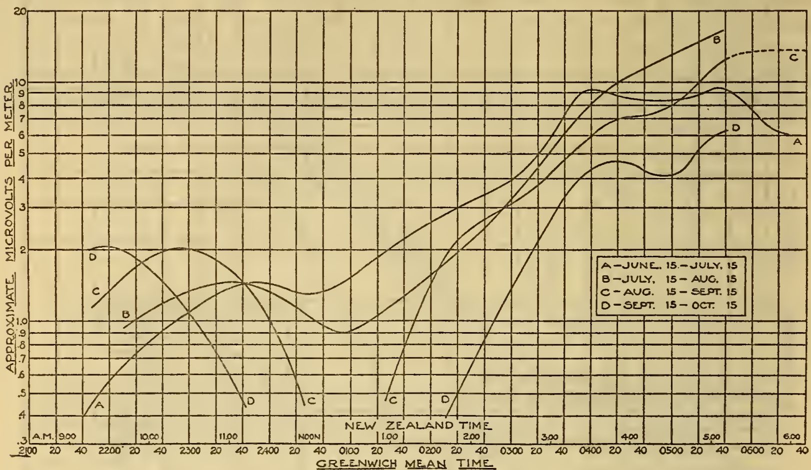


Figure 6.—*Average diurnal variation of signal intensity of station W8XK, Pittsburgh (11,880 kc), observed at Dunedin, New Zealand, 1929*

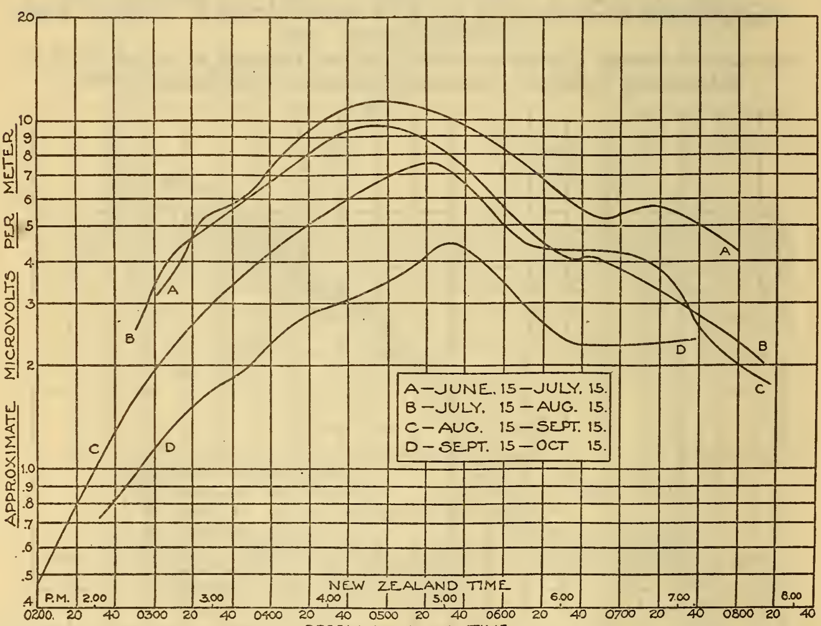


Figure 7.—*Average diurnal variation of signal intensity of station W6XN, San Francisco (13,830 kc), observed at Dunedin, New Zealand, 1929*

A study of the daylight-darkness graphs shows that the portions of the two paths from Rugby to Dunedin which are light in June at noon are dark in December at midnight. The signal, therefore, must traverse opposite paths around the earth at noon, June, and

midnight, December, and as the lengths of the daylight-darkness portions of these paths are about the same, at these times, we should expect, as observed, that reception conditions would be somewhat similar.

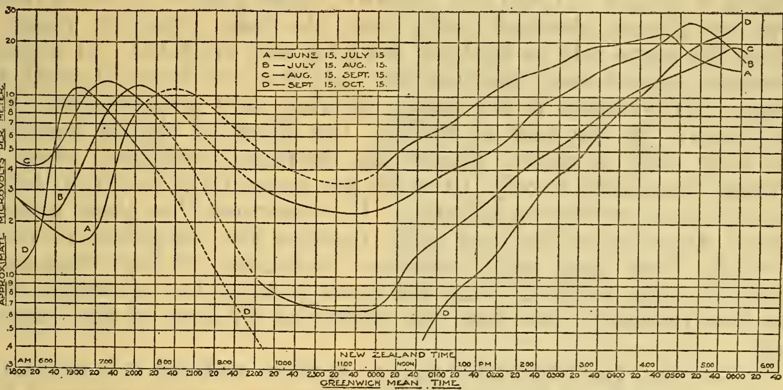


Figure 8.—*Average diurnal variation of signal intensity of station PCJ, Eindhoven (9,560 kc), observed at Dunedin, New Zealand, 1929*

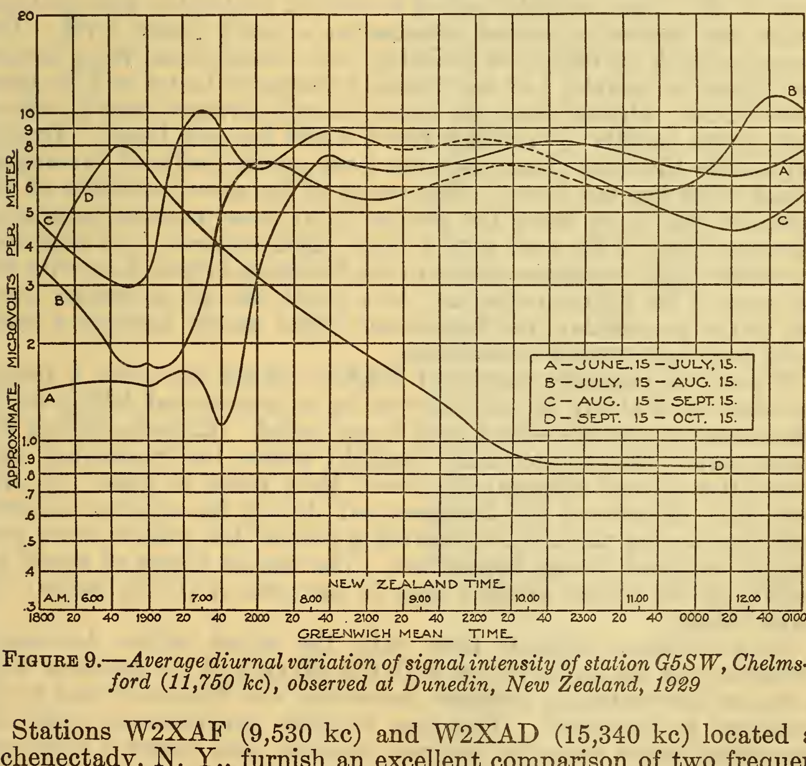


Figure 9.—*Average diurnal variation of signal intensity of station G5SW, Chelmsford (11,750 kc), observed at Dunedin, New Zealand, 1929*

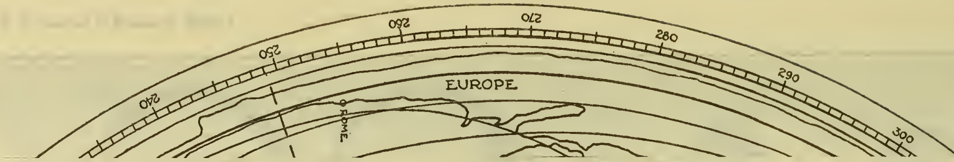
Stations W2XAF (9,530 kc) and W2XAD (15,340 kc) located at Schenectady, N. Y., furnish an excellent comparison of two frequencies over the same path. It is seen that the higher frequency reaches a maximum much earlier in the day, as might be predicted. It is

of great interest, however, to note that field intensities at both frequencies rise at very nearly the same rate up to sunset. For any particular month, the rate of advance of the darkness wall is nearly uniform throughout the afternoon over this path. Study of the graphs of W8XK (11,800 kc), Figure 6, yields almost the same results over an almost identical path, with the field intensity rising at about the same rate as that for W2XAF and W2XAD. It appears, therefore, that during this time the nature of the losses through this range of frequencies is the same, differing only quantitatively with frequency. In the case of W8XK, the effect on signals traversing the long path is shown during the morning reception, when the average maximum is only 10 to 20 per cent of (15 to 20 db below) the afternoon average maximum. It is assumed that these morning signals arrive over the long path, because the conditions of nearly a wholly dark long path indicate a condition of low attenuation which is again fulfilled along the short path in the afternoon when the field intensity rises with the westward advance of the darkness wall.

In studying the September curves of these stations it is noted that at 2.15 p. m., N. Z. T., the daylight-darkness path is identical with that in June at the same time, while the signals are uniformly less than 20 per cent of (14 db below) the June values. Prior to 2.15 p.m., N.Z.T., the daylight path is shorter in September than in June, while the September signal remains at a much lower level. The causes of such an effect are probably very complex and must always be difficult to isolate, but one possibly pertinent factor will be mentioned here. During June, the darkness wall advances over the signal path quite rapidly (averaging about 4,800 km per hour). During September this rate of advance has been greatly reduced (averaging about 2,800 km per hour). The result of the slower advance of the darkness wall is to leave the similar night areas in more prolonged darkness than is the case with a more rapid advance. In addition, an earlier night condition occurs in the Northern Hemisphere with the advance of the autumn season. As a result, though at certain times the paths are similar, the September signal passes through a much more prolonged period of darkness.

The signal intensity graphs of W6XN (13,830 kc) show a steady increase until about sunset followed by a pronounced falling off as the darkness over the signal path is prolonged. Likewise during the transmission through partially daylight paths, the September field intensities appear substantially lower than those of June. In this case also, advance of the darkness wall during the equinox is about half that during the solstice, leaving a part of the path in more prolonged darkness during September. The sunset values of signal intensity in September are less than 20 per cent of (14 db below) the June values.

Such evidence suggests that while the signal suffers decreasing absorption in the ionized layer with the advance of the darkness wall, a second loss occurs, in darkness, increasing with frequency and as the darkness is prolonged. This loss becomes predominant after the maximum signal intensity has been reached, and causes a comparatively rapid drop in the signal intensities of the higher frequencies some time before sunset, becoming noticeable on the lower frequencies progressivley later.



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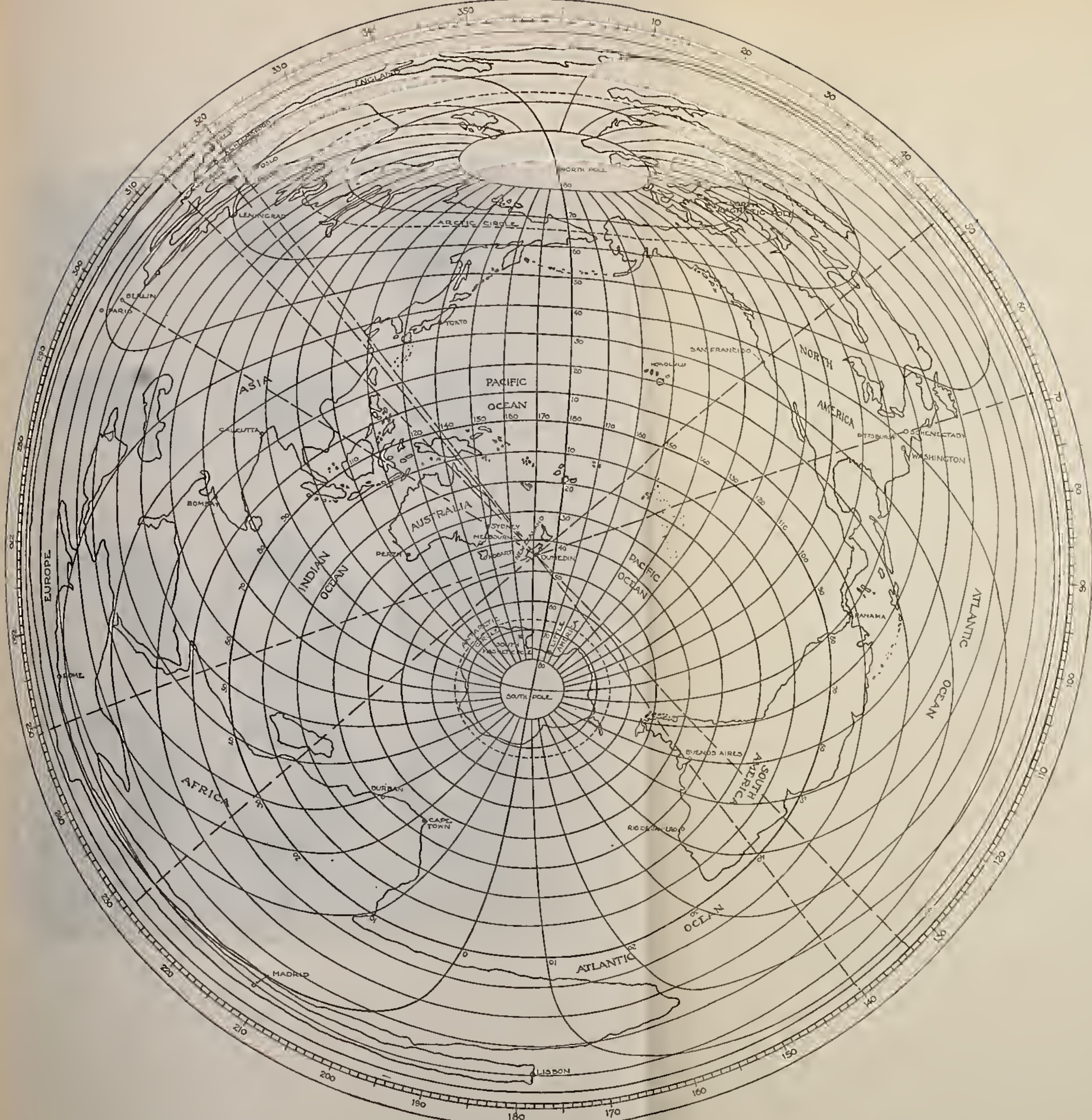

FIGURE 10.—*Chart of the world, showing great-circle distances and azimuths, from Dunedin, New Zealand*

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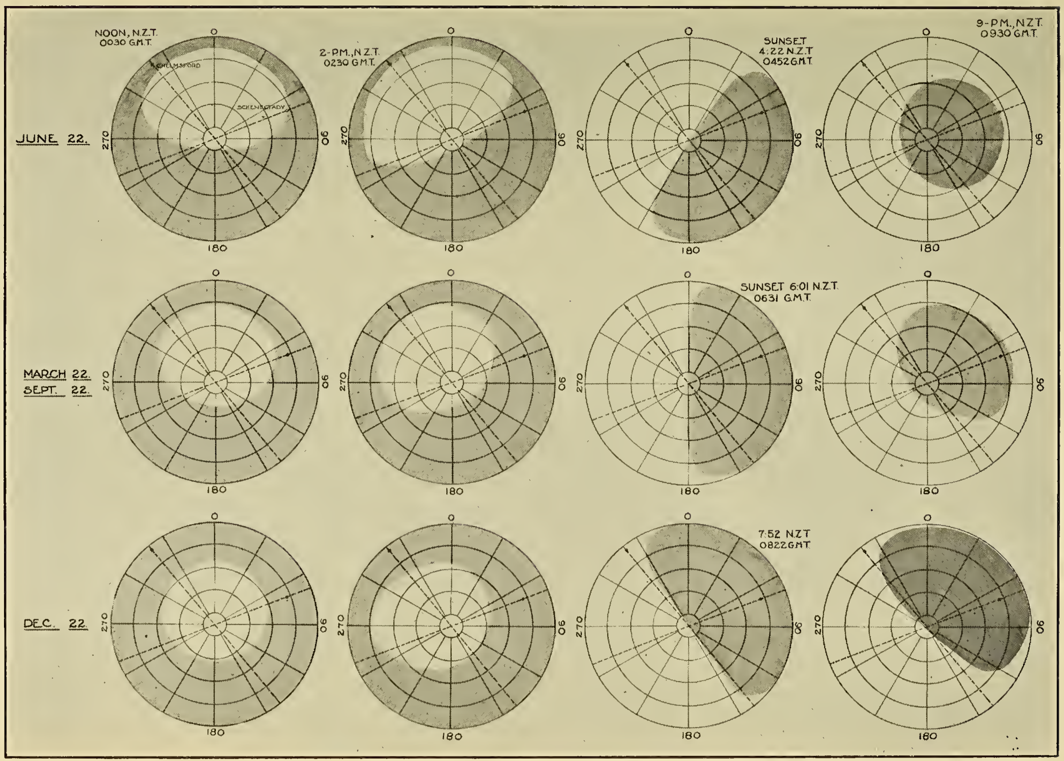

FIGURE 11.—*Diurnal and seasonal variation of daylight and darkness along any path from Dunedin, New Zealand (171 E. 46S.) Morning*

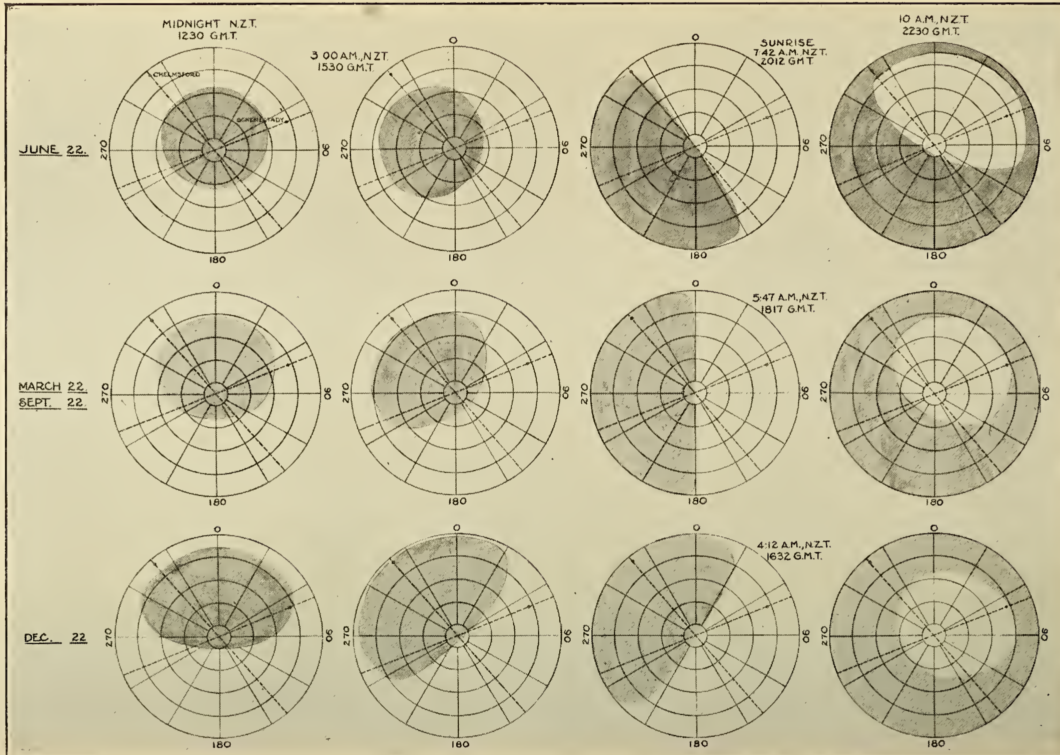

FIGURE 12.—*Diurnal and seasonal variation of daylight and darkness along any path from Dunedin, New Zealand. (171 E. 46S.) Evening*

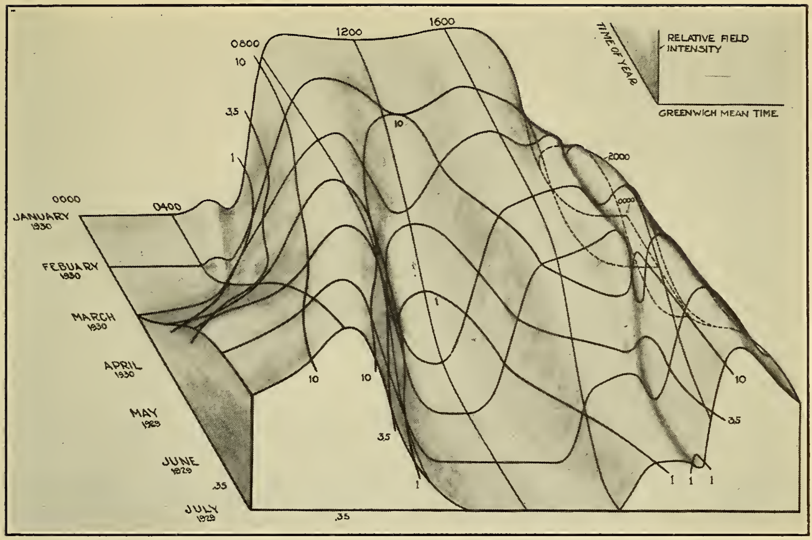

FIGURE 13.—*Diurnal and seasonal variations of relative field intensity of GBX, Rugby (10,280 kc), observed at Dunedin and Awarna, New Zealand, 1929-1930*

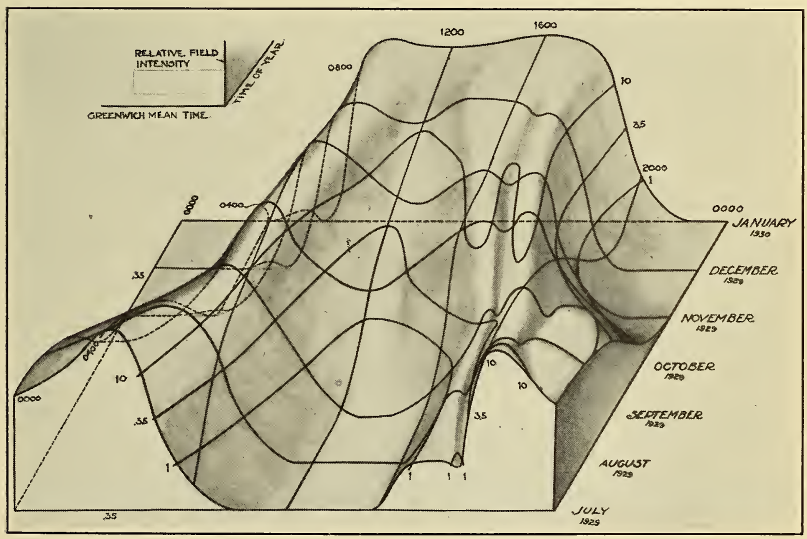

FIGURE 14.—*Diurnal and seasonal variations of relative field intensity of GBX, Rugby (10,280 kc) observed at Dunedin and Awarna, New Zealand, 1929-1930*

It is to be noted in the case of PCJ (9,560 kc) that, in general, the variations in signal intensity follow the changes in daylight and darkness along the path. About midday (N. Z. T.), however, the length of the daylight path traversed starting at 10 a. m. to noon (N. Z. T.) decreases nearly uniformly, though slowly (averaging about 600 km per hour). At the same time the signal strength also decreases slowly. In the afternoon the darkness wall continues to approach at about the same rate while the signal rises quite rapidly, reaching fairly fixed values for given lengths of daylight and darkness paths during the period observed. For instance, at noon in June, the nature of the path is the same as at 3 p. m. in September, and the average signal at these times is the same. In this case the rate of change of daylight along the path is about the same in June as in September.

It appears that during the morning the advance of the darkness wall was so slow that the attenuation in the transmitting layer along the daylight portion of the path actually increased faster than the decrease in attenuation due to the advance of the darkness wall.

Another major deviation of change in signal intensity from the usual change with the daylight and darkness path will be mentioned in the case of G5SW. From Figures 2 and 9 it is seen that shortly before sunrise in June, the signal falls suddenly to a decided minimum, followed quickly by a very rapid rise of 10 to 20 times (20 to 25 db). Typical cases of original records are shown in Figures 15 and 16. This minimum occurs at about 7.10 a. m., N. Z. T., in June. By September this phenomenon has entirely disappeared. It is seen from Figures 11 and 17, that in June the signal path lies nearly parallel to the sunrise-sunset path. Up to 8 a. m., however, no marked variation is taking place in the retrogression of the darkness wall along the great-circle path, which might account for the sudden and large changes in signal intensity. In fact it might be expected from a general study of the daylight-darkness charts that a steady increase would take place throughout this period with a dip after 8 a. m., when the received signal would appear to change from the direct to the reverse path around the earth.

If the signal path is assumed to be shifted from 12° to 18° toward the poles, it appears that this phenomenon could be explained. Under these circumstances: (1) Up to 7.10 a. m., N. Z. T., the June signal rapidly decreases as the assumed path suddenly becomes all daylight; (2) at about 7.10 a. m., N. Z. T., the daylight along the two assumed paths becomes about equal and maximum, and the signal is a minimum; and (3) from 7.10 a. m., N. Z. T., to sunrise, the darkness rapidly increases along the assumed reverse path, reaching a maximum about 10 minutes after sunrise when the signal is a maximum.

This condition of fading becomes less and less marked as the season progresses until it has disappeared when the equinox is reached. There appears to be some indication, therefore, that some such shift in direction may take place, and that the signal may not necessarily travel along the great-circle path along the earth. Consideration of the earlier sunrise at the approximate Kennelly-Heaviside layer altitudes does not appear to alter the above discussion.

On the basis of this discussion, it might be predicted that a similar condition of fading would take place before sunset during midsummer. That this is actually the case is shown in Figures 13 and 14, a dip occurring about 7.15 p. m. N. Z. T. during December, whereas such

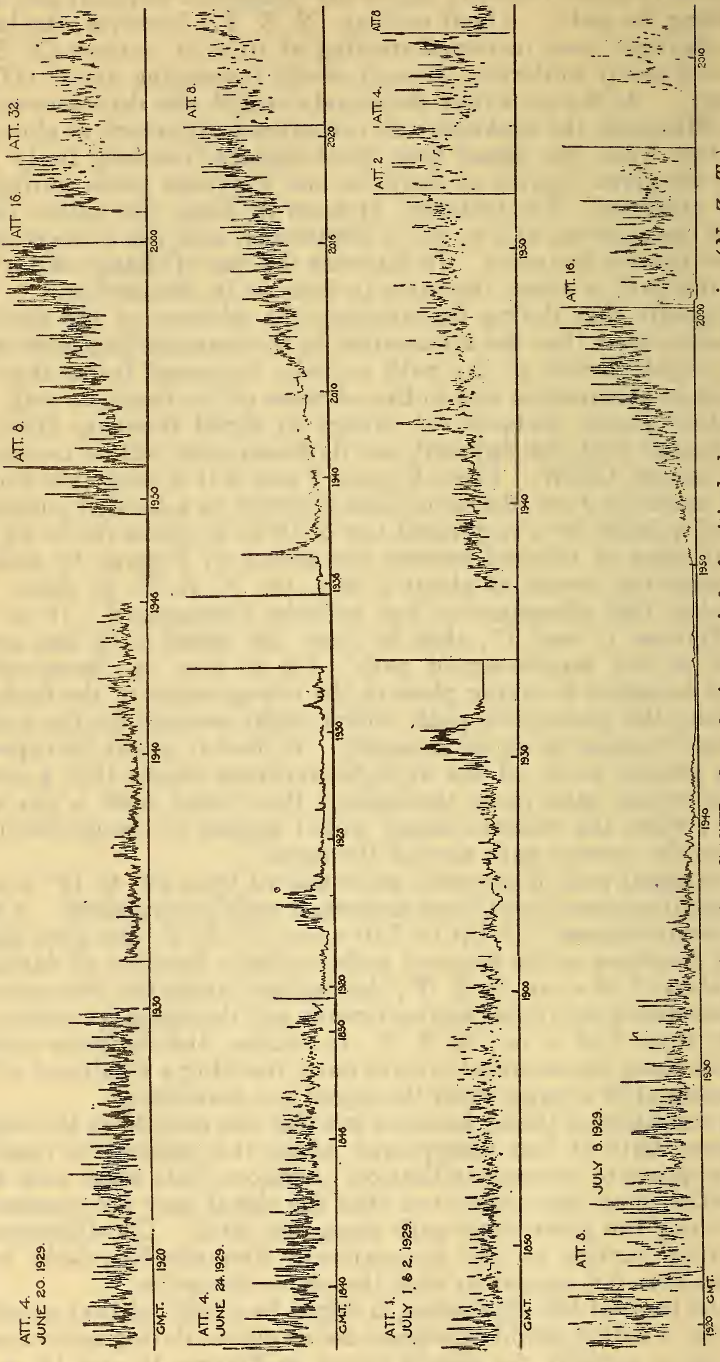

FIGURE 15.—*Record of station G5SW taken during period of critical change near sunrise (N. Z. T.)*

NOTE.—"ATT." indicates the value of attenuator step in the amplifier.

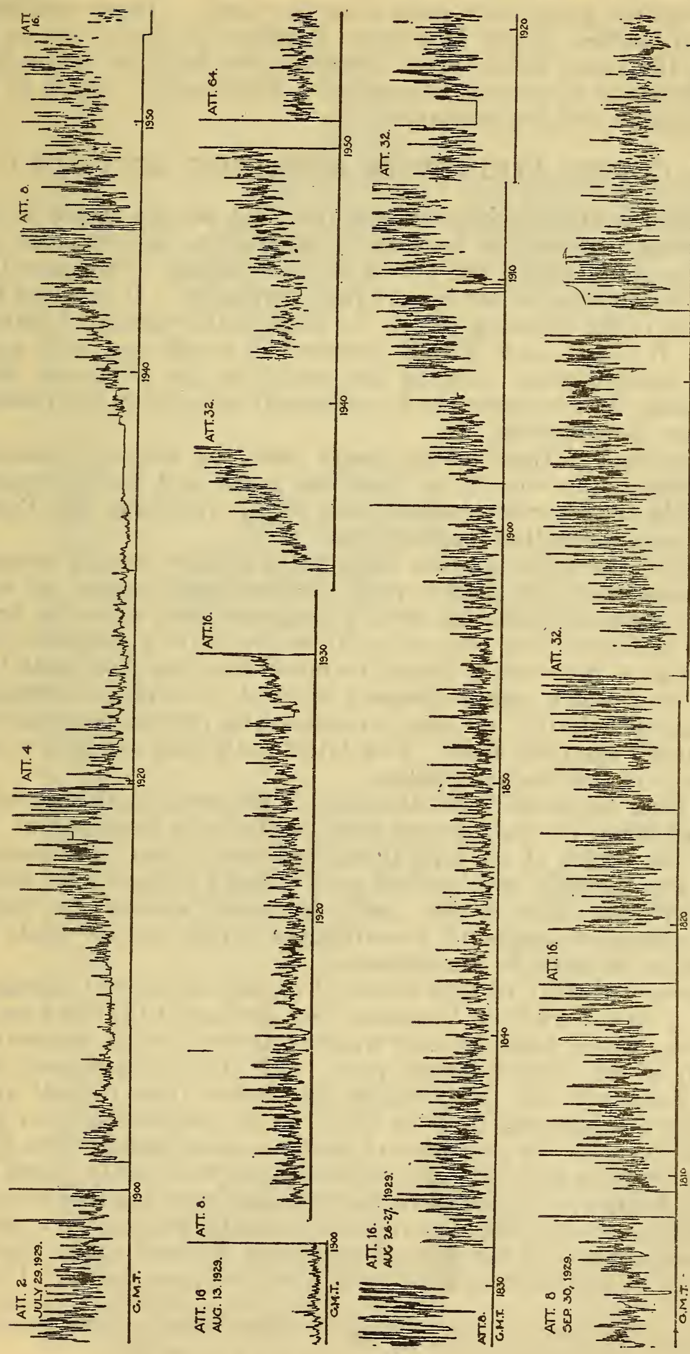

FIGURE 16.—*Records of station G5SW showing transition of period of critical change to a fairly steady condition with progression of season*

a change would be expected about an hour later were the signal to travel along the great circle path along the earth. These conditions are not so marked during December, however, probably due to the fact that the signal must travel through more daylight in the New Zealand summer afternoon because of a difference of about 9° between Dunedin and the antipodes.

V. CORRELATION WITH MAGNETIC ACTIVITY [3]

Examination of the measurements from day to day shows no evident general correlation between transmission disturbances and magnetic activity during the period of observations. One exception, however, indicates a rather remarkable correlation. It is noted that large losses in the morning (N. Z. T.) (long path)[4] signals of stations W2XAF, W2XAD, and W8XK occurred in every case with major magnetic disturbances. During the same day, the afternoon (short path) signals did not appear to be materially affected in the presence of the same disturbances.

Investigation of these paths shows that the longer (disturbed) path passes in the vicinity of both the north and south magnetic poles, while the shorter (undisturbed) path, traversing the Pacific, does not pass near either magnetic pole.

A study of the angle between these paths and the earth's magnetic field [5] shows that the shorter path (undisturbed) makes an angle averaging about 45° with the earth's magnetic field, while the longer path has portions lying perpendicular to the earth's magnetic field. In this respect, however, it should be noted that the short path from Europe (over which signal intensity showed no evident correlation with magnetic activity) has, also, a considerable portion perpendicular to the earth's magnetic field. This latter path does not pass so near the vicinity of the magnetic poles.

It has been suggested [6] that the effect of magnetic storms should be first noted when the path comes into the daylight hemisphere. Because of the length of the long (disturbed) path from American stations, it was the only path studied over which a portion must always be in daylight. The shorter path, however, showed no marked evident effects of magnetic dusturbances which started while this path was in the daylight hemisphere.

An incident worthy of note occurred during the second passage of the *City of New York* from Dunedin, New Zealand, to Little America, Antarctica, during which stormy weather drove the ship westward in proximity of the south magnetic pole. (Fig. 18.) About noon (0000 GMT), February 12, 1930, signals fell below their normal value, practically disappearing by 0600 GMT on all frequencies from 1,000 to 20,000 kc, with the exception of much reduced signals from WFA at Little America and extremely weak signals from LSD, Argentine, and VIS, Australia. Calls on regular schedule were made in an effort to establish contact with American commercial stations, but subsequent examination of the logs of scheduled stations shows that no indications of signals from the *City of New York* were heard. Condi-

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[3] Anderson, C. N., Correlation of Long Wave Transatlantic Radio Transmission with Other Factors Affected by Solar Activity, Proc. I. R. E., p. 297; 1928.
[4] Anderson, D. N., Transatlantic Radio Transmission, Proc. I. R. E., p. 1528; 1929.
[5] Eckersley, T. L., An Investigation of Short Waves, J. I. E. E. (London), p. 992; 1929.
[6] Maris, H. B., and Hulburt, E. O., Wireless Telegraphy and Magnetic Storms. Proc. I. R. E., p. 494 1929.

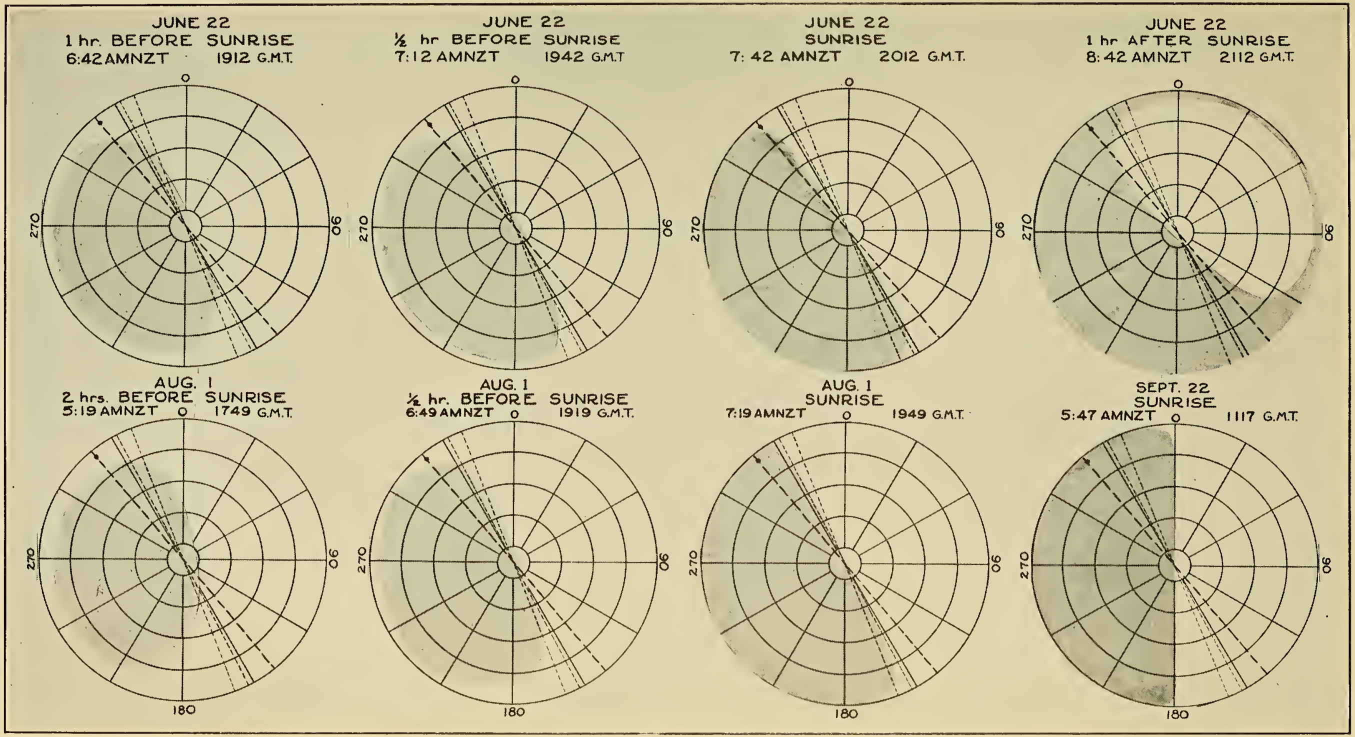

FIGURE 17.—*Seasonal variation of daylight and darkness along signal path through sunrise from Chelmsford, England, to Dunedin, New Zealand*

tions recovered slightly by noon, February 13, again becoming bad by 0600 GMT. General recovery was noted by the evening of February 14. During this period a major magnetic disturbance took place corresponding almost exactly to the disturbed transmission period. Though WFA, Little America, about 600 miles farther from the magnetic pole to the southeastward, noted much reduced signals, ordinary communications were carried on throughout the disturbed period. This would indicate that the effect was largely localized in the vicinity of the magnetic pole.

It is of interest that during September, 1929, when lower values of signal intensities were noted for all of the American stations, the

FIGURE 18.—*Position of "City of New York" during magnetic storm, Feb. 12 and 13, 1930*

Wolfer sun spot number was a minimum for the year. It is of equal importance, however, that European signals did not appear to show any marked variations in intensities during this time, so that it is doubtful if the low sun spot number had any bearing on the matters previously discussed.

VI. SUMMARY

It is, of course, impossible to draw any very general conclusions from the data obtained over such a limited period. It is known that these conditions are not exactly repeated from year to year, due to solar effects and, perhaps, other unknown factors. Mr. Shiel, of

Dunedin, for instance, reports the signals of 2XAD rather erratic during 1930–31; that is, not nearly as regular as during the period of measurement. However, certain repeated occurrences through the frequency ranges and paths considered may be mentioned:

1. In general, a signal minimum occurs over a wholly light path.
2. A rise in signal intensity generally occurs as the path becomes partially dark, higher frequencies rising and reaching a maximum progressively before the next lower frequency.
3. A steady fall in signal intensity occurs after the maximum has been reached, starting progressively down from the higher frequencies and becoming most pronounced after the path has become wholly dark. The transmission conditions do not appear to become fixed or steady either during daylight or darkness. A secondary rise and maximum is frequently observed as daylight approaches the transmitting end of the path.
4. An apparent diminution in signal intensity takes place generally for a given daylight-darkness path, when the darkness portion is prolonged.
5. A decrease in signal intensity appears to take place when the darkness wall is advancing so slowly as to apparently allow the attenuation along the prolonged daylight portion of the path to increase more rapidly than the diminution in attenuation at the advancing darkness wall.
6. A shift of the signal path may take place under certain circumstances, as suggested.

VII. ACKNOWLEDGMENTS

The writer wishes to acknowledge the support given this work by the Aeronautics Branch, Department of Commerce, through providing funds. He also acknowledges his indebtedness to Dr. J. H. Dellinger, T. Parkinson, S. S. Kirby, and T. R. Gilliland, of the Bureau of Standards, who made possible the project and supervised the assembly of the equipment; to the Post and Telegraph Department of the New Zealand Government, Mr. Gibbs, chief engineer, Mr. Macey, district telegraph engineer, and Mr. Head, chief operator of the Awarua radio station, who made possible the field station and lent their aid in making its operation successful; to Lalor Shiel, Dunedin, New Zealand, who very kindly aided in the measurements and made his factory shop facilities available; to Dr. Jack, University of Otago, for his assistance; and to the writers' colleagues on the expedition for their cooperation and assistance.

Washington, November 14, 1931.